PTERASPIS LEATHENSIS WHITE A DITTONIAN ZONE-FOSSIL

By ERROL IVOR WHITE

SYNOPSIS

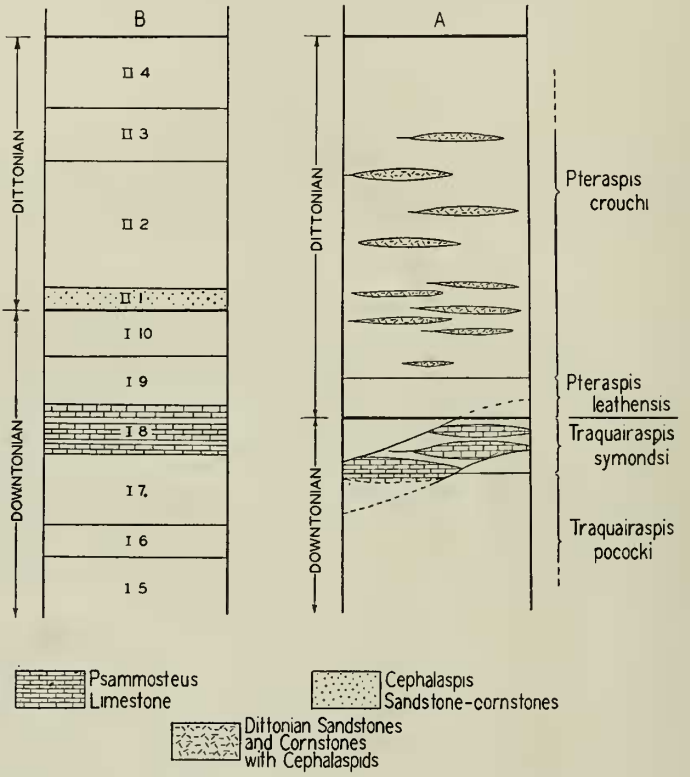
The Lower Old Red Sandstone species *Pteraspis leathensis* White, from the Anglo-Welsh area, is described in detail and compared with Continental species with which it is considered to form a new sub-genus, *Simopteraspis*. Its use as a zone-fossil in the Dittonian is demonstrated.

I. INTRODUCTION

Pteraspis leathensis is the earliest species of this genus recorded from Great Britain and is of special interest on that account alone. Moreover, although published records name only five localities from which it has been obtained (King, 1934: 534, 541; White, 1935, text-figs. 30, 31, 38, and 77), subsequent discoveries have shown that this species has apparently a wide geographical distribution, at least within the Anglo-Welsh area, and a limited stratigraphical range within the Lower Old Red Sandstone, so that its value as a potential zone-fossil in this intractable series is obvious. Indeed, not only has it already been used as such (White & Toombs, 1948), but the zone, which follows immediately that of *Traquairaspis* [*Phialaspis*] *symondsi*, is taken as the revised base of the Dittonian Series (Text-fig. 1), since it is here rather than later, as originally put forward by Wickham King (1925, 1934), that a significant change takes place in the vertebrate faunas of the Lower Old Red (p. 56 *supra*). The species was not described until 1934, but it had been recorded by King in 1921 (as *Cyathaspis leathensis*), and later (1925: 387) again without locality, as occurring 'in or near the *Psammosteus* Limestones', which is approximately correct, although these beds were reckoned as Downtonian by King, who placed the base of the Dittonian considerably higher, within our zone of *Pteraspis crouchi*. The first locality actually mentioned by King (1934: 534) was Ammons Hill; at the same time he extended the range of the species upwards into his Dittonian (ibid.: 446), but no confirmation of this has been forthcoming, and it seems likely that this suggestion was based on the mistaken identification of plates of juvenile specimens of *P. crouchi* or some other species. It is surely significant that in none of the numerous localities from which *P. leathensis* has been obtained have specimens of the other species of *Pteraspis*, typical of the succeeding zones, been found, and in the only two areas from which both *P. leathensis* and the earlier zone-fossil *Traquairaspis symondsi* have been collected, in Lye Stream (loc. 7*b*) and near Brecon (8), the two zones are clearly distinguished.

Whether the '*Psammosteus* Limestones' phase does actually invade the zone of *P. leathensis* (or, to put it the other way, as Wickham King has reported, whether *P. leathensis* occurs in the *Psammosteus* Limestones) is not yet clear (see Lye Stream section, p. 74 *infra*), but since that phase is almost certainly diachronic, it seems possible that it does.

Outside the Anglo-Welsh area closely related species have been found in north France and Spitsbergen, in the former the resemblance being so close as to suggest possible identity when the French fossils are better known.



TEXT-FIG. 1. Diagrammatic representation of the classification of the Dittonian and upper Downtonian strata of the Anglo-Welsh region used in this work (A) compared with that of Wickham King, 1934, (B) to show the diachronic nature of the '*Psammosteus* Limestones' and the general distribution of sandstones and cornstones with Cephalaspids for comparison with the supposed '*Cephalaspis* Sandstone-Cornstones' of King.

II. THE LOCALITIES AND ASSOCIATED FOSSILS

1. *Leath 1 (or Leath Stream), Corvedale, Salop.*

'Leath Stream (1) is a rivulet on N. side of the road at Leath Bank, the steep hill on road from Ditton Priors to Holdgate and Stanton Long. There is one cottage on the side of this road at Leath Bank and the section (in rivulet) is a little to E. of this cottage. This is I. 8 but it is high up in this stage as the hard band (in I. 8 base at Earnstrey [slightly less than a mile away to the SW.]) crosses Leath Bank below and W. of the cottage and its garden on that bank—all specimens [from] Leath Stream (1) I. 8 are out of this rivulet E. of this cottage.' (W. W. King *in lit.*

16 June 1945.) Some of the specimens are labelled 'Lower band' or 'Lowest band'.

This is the type-locality. The specimens include the holotype, the external impression of an almost whole but completely flattened dorsal shield, and about a dozen other specimens, mostly ventral disks, but including one deep flank-scale (B.U.11[1]), a fine dorsal spine and socket (P.14522), and an impression of the left antero-lateral region of a dorsal shield (P.16853*ii*). The specimens are shown either from the inner side (now often developed as external impressions) or the outer surface, and although usually crushed the preservation of the external ornamentation is very fine. The fossils are black in a matrix of light grey muddy limestone with much carbonaceous material on the exposed surface and some *Pachytheca*. No other fossils have been obtained.

2. *Ammons Hill, Bromyard, Herefordshire*

The section is in the railway cutting between Suckley and Bromyard stations on the B.R.(W.R.); it is described in some detail by Wickham King (1934: 533–4) who records all his stages from I. 7 to II. 2, of which stages I. 7 (part) to I. 10 comprise some 440 ft. of strata. This might be expected to cover approximately the Downtonian zones of *Traquairaspis pococki*, *T. symondsi*, the Dittonian zone of *Pteraspis leathensis*, and part of that of *P. crouchi*, but the section is now much overgrown and of these zone-fossils only *P. leathensis* has been collected. Wickham King records specimens only from his stage I. 9 (according to his unpublished section from bed '11' in the middle of the stage) in 'dark green, very fine silts and marls', with *Didymaspis grindrodi*, 'Acanthodian spines' (these specimens have not been traced), mollusca, eurypterids, and *Pachytheca*, but a ventral disk collected by him (P.16537–8) is labelled 'top part of I. 8'. The specimens described below, chiefly collected by Messrs. W. N. Croft and R. P. Tripp, are in a fine red sandstone, sometimes mottled green and somewhat calcareous, which apparently lies immediately over King's bed '11' and at least 140 ft. above the 'Psammosteid Limestone' marked at the base of stage I. 8 in King's measured section of the cutting. *P. leathensis* seems, therefore, to have been collected at more than one level. The fauna associated with the red sandstone specimens, which include the uncrushed external impressions of one complete and several fragments of dorsal shields and of a number of isolated ventral disks (Text-figs. 3–5, 9), comprises an *Onychodus* spiral (P.23746) and other undetermined plates and spines.

3. *Dinmore Hill, Herefordshire*

Dinmore Hill is $7\frac{1}{2}$ miles north of Hereford. W. S. Symonds (1872: 222) remarks that 'Fish plates were found in the tunnel [i.e. the railway tunnel through the hill], but I saw nothing new or worthy of remark'. A single small and imperfect ventral disk in counterpart with ornamentation typical of *P. leathensis* (P.16543–4) was collected by Mr. Wickham King 'by tunnel shaft, near top of ridge near road to Leominster, I. 8'.

[1] Specimens lettered 'B.U.' belong to the Geological Department of Birmingham University; 'RP' and 'De' to H.M. Geological Survey; 'P.' to the British Museum (Natural History).

4. *Porch Brook, Rock, Worcestershire*

R. W. Pocock, who discovered this fossiliferous locality, described the exposure as '*Anglaspis* Bed (Top Bed) 550 yds. S. of Whitehouse Farm. In Porch Brook'. L. J. Wills's exposure, from which came most of the specimens considered here, is described as '500 yds. S. by W. of White House Farm ¾ (mile) SE. of Rock near Bewdley'. According to Wickham King the stage is I. 8 (*in lit.* 20 June 1945).

The rock is a light grey calcareous siltstone on which the remains of the Ostracoderms, black in colour, are freely scattered (Text-figs. 6–8, 10–14; Pl. 5, Figs. 1–5). The specimens are mostly quite small fragments and scales but include a few large pieces of dorsal shields. Identifiable remains of ventral disks are rare. Curiously enough, while the shields are very much smaller than those from other localities the scales are relatively very large. Most of the fossils show their outer surfaces, which are very well preserved.

Besides the remains of the *Pteraspis*, which constitute the bulk of the material, pieces of *Anglaspis* (e.g. P.25250), presumably *A. macculloughi*, are numerous, with scales of a *Thelodus* (*T.* cf. *schmidti*) (e.g. RP695), a few fragments of ichthyodorulites, and scales and fragments of plates of one or more undescribed Ostracoderms with characteristic ornamentation. The underside of the slabs, that is to say, about an inch above or below the Ostracoderms, there is much carbonaceous material, with an occasional *Pachytheca* and more rarely pieces of the Ostracoderms poorly preserved.

5. *Holbeache, Trimpley, Worcestershire*

A single specimen labelled 'Holbeache 6' was collected by Wickham King from an exposure in the plantation, rather more than 100 yds. north-east of Holbeache House, 'by the cart track to Payne's Cottage'. In this track Roberts (1860: 104) was able to 'knock out a *Pteraspis*', presumably from the same bed. This is about a furlong from the spot where *Traquairaspis* [*Phialaspis*] *symondsi* was found (White, 1946: 211). Unfortunately the relative levels of the two finds have not been clearly determined.

The specimen (P.24791) consists of a crushed ventral disk showing the outer surface overlying an inverted dorsal disk with a branchial plate at the side—probably the remains of a single carapace. Another fragment lies near by. The specimens are black on a gritty greenish cornstone with yellow pellets.

6. *'Near Trimpley', Worcestershire*

The exact provenance of these three ventral disks is unknown. The matrix is a fine-grained, light grey sandstone, and the one actual plate (now etched to form an external impression, B.M. (N.H.) 42159*a*) was similar in colour. The other specimens are internal impressions (42159, the counterpart of the plate previously mentioned, 42160, 42160*a*—see White, 1935, text-figs. 38, 77) of medium size, measuring 3·5–3·7 cm. in length. They are almost undistorted, and show well the shape and curvature of the plates. Recently a fourth specimen, 42160*b*, the internal impression of a dorsal shield as small as the Porch Brook specimens, has come to hand. Its matrix is similar to but rather bluer than that of the ventral disks and it is simply labelled

'Trimpley'. All these specimens are from the Baugh Collection and were discovered before 1870.

7. Exposures near Morville, Salop.

To the south and south-west of Morville, 3 miles west of Bridgnorth, seven localities have yielded small vertebrate faunas with *Pteraspis leathensis*. Six of these were discovered during the 1929 survey of the area, and in the Summary of Progress of the Geological Survey for 1929 (p. 50) it is stated that 'Fish beds, probably belonging to the Lower Old Red Sandstone (Dittonian), have been detected by Mr. Pocock in the sandstones and marls above the *Psammosteus* Limestone of Meadowley Hill, and at localities in the area to the south-west round Criddon and Chetton'. More details are given in the recent memoir (Whitehead & Pocock, 1947: 22).

Three of the Survey exposures (*c*, *d*, *g*) were loose blocks, but those clearly in place (*a*, *e*, *f*) were above the '*Psammosteus* Limestones' according to the Survey mapping. Mr. Wickham King's manuscript maps agree with this except in respect of Yewtree Dingle (*e*), where he places the '*leathensis*' exposure just below the '*Psammosteus* Limestones'. Both these conflicting statements may well be true, for the '*Psammosteus* Limestones' stage (I. 8) as defined by King (1934: 527) is up to 150 ft. thick and may contain more than one limestone (see Text-fig. 1). It was originally designated a zone, but recent work (White & Toombs, 1948: 7) indicates that it was a diachronic phase which occurred in at least two zones (*Traquairaspis pococki* and *T. symondsi*) and possibly still higher in that of *Pteraspis leathensis*, a suggestion which may explain the above apparent contradiction. Indeed, it was at first thought that in the Lye Stream section (*b*) full proof was forthcoming, since beds containing *P. leathensis* have been found both above and below the representative of the limestone phase, but later investigations throw much doubt as to the lower bed being in place, a doubt which also applies to the finds at some of the other localities (e.g. (*c*), (*d*), and (*g*)), all of which except (*a*) lie on the arc of the Meadowley–Aston Hill ridge within a distance of $\frac{3}{4}$ mile.

The matrices are for the most part grey sandstones or marls, occasionally cornstones with variable lime-content. The fossils, which are also light in colour, are often fragmentary, but do include some fairly complete dorsal and ventral disks on which the ornamentation is well preserved, and there are also a number of good internal casts.

Wills (1948: 28 footnote) records a small slab from Morville with 3 ventral and 30 dorsal disks, of which 'all but four lie upside down, as if the animals in dying had turned turtle and had then been stranded on their backs on the muddy bottom of a pool. Presumably as decomposition set in, the other parts of the skeleton were drifted away by currents.' This is a singular explanation of an effect of water-sorting. Quite apart from the unlikelihood of mud being left behind by a current that could carry away the ventral disks and branchial plates, we would suggest that saucer- or cup-shaped objects, unless subjected to violent movement, tend to sink in water with the convex surface downwards, since that surface presents less resistance than the concave side to passage through the water (the same, of course, applies reversely to objects rising in air). On the other hand, if the plates had been further subjected to stream-pressure after settling, they would presumably have followed the example

of Richter's pelecypod valves (Arkell, 1943: 147) and have come to rest with the convex surface upwards. Current- or water-sorting is commonly met with in the Lower Old Red sandstones (see White, 1938: 110; 1946: 215) and in some cases not only are the types of plates segregated, but the plates are more or less uniformly orientated. The determining factor in water-sorting is not size, as Wills suggests, but buoyancy, depending on shape and specific gravity, e.g. it is often the case that the domed dorsal and the flat ventral disks of *Traquairaspis*, of approximately the same size, are found in separate localities.

The localities are as follows, the details, except in the case of (*b*), being those given on the labels of specimens in the Geological Survey, most of which were collected by or at the instance of Dr. Pocock:

(*a*) Section in south bank of brook, 930 yds. S. 5° W. of Meadowley Farm, and 2,490 yds. S. 9° W. of Morville Church. [Also given as 'Stream bank section 700 yds. NE. of Criddon Farm near Chetton' and in Whitehead & Pocock, 1947: 22, as '700 yds. upstream from Criddon Bridge'.]

Associated with the *Pteraspis* plates (e.g. De3881–7, RP331) are scales of *Thelodus* cf. *schmidti* (e.g. De3884), fragments of an undescribed Ostracoderm or Arthrodire (De3883*a*) and *Pachytheca*.

(*b*) The Lye Stream, 490 yds. W. 17° S. to 800 yds. W. 23° S. of Lye Bridge. This is a most important section, for it exposes some 150 ft. of roughly horizontal strata, and clearly establishes not only the relationships between the *Traquairaspis symondsi* fauna and that of *P. leathensis*, but also the diachronism of the '*Psammosteus* Limestones', since it is only here and elsewhere in this area that they are found above *T. symondsi*. Mr. H. A. Toombs, who made a detailed study of the section, found towards the base, at about 370 ft. O.D., a hitherto unrecorded bed with *Traquairaspis symondsi*, in which the zone-fossil was well and plentifully preserved. Some 60 ft. above this were blocks in the bed of the stream, containing plates of *P. leathensis* (e.g. P.26932) and fragments of *Poraspis* (P.26931) and *Onchus* (P.26934). It was at first thought that these blocks were actually in place (White & Toombs, 1948: 12), but the section contains much down-wash and the probability of their having been carried or fallen from above must be accepted. Fifty feet above these the '*Psammosteus* Limestones' phase is represented by 30 ft. or more of markedly calcareous marls with discontinuous limestones, and above this again sandstones and cornstones have yielded *Pteraspis leathensis* (P.26927–9) and *Poraspis* (P.26930) in place, about 140 ft. above the *T. symondsi* bed. So far no other fossils have been detected in any of these beds, except *Tesseraspis* (e.g. P.26918–19) and a single head-shield of a small *Cephalaspis* [B.U.506], not identifiable as to species, which come from or near the *T. symondsi* bed.

(*c*) Block in road 450 yds. SW. of Lye Mill (and about 1,200 yds. SSE. of Morville Church). *Pteraspis leathensis* (e.g. RP320, 322). No associated fossils.

(*d*) Meadowley Hill, 450 yds. W. of Lye Mill (and about 800 yds. SSW. of Morville Church). In the block with *P. leathensis* were found *Onychodus* teeth (RP315) and fragments of an undescribed Ostracoderm or Arthrodire (RP313).

(*e*) Section at head of Yewtree Dingle 1,180 yds. WSW. of Morville Church. Associated fossils are *Poraspis* sp. (De3907), *Thelodus* scales (De3905*a*, 3906), a

ribbed spine (De3906), and *Pachytheca*. Wickham King places this exposure just below the '*Psammosteus* Limestone'; Pocock, 50 ft. above it.

(*f*) Aston Hill, 800 yds. WSW. of Morville Church. *P. leathensis* (e.g. RP303). There are no associated fossils. Wickham King maps this exposure as just above the '*Psammosteus* Limestone', but Pocock places the limestone some 50 ft. lower.

(*g*) Aston Hill Wood, loose blocks in bank side, 500 yds. SSW. of Morville Church. With *P. leathensis* (e.g. De3892) were also found a Cephalaspid (De3897, 3898*a*) and indeterminable ichthyodorulites (e.g. De3899). L. J. Wills has also collected from near here ('$\frac{1}{4}$ mi. SSW. of church') good fragments of *P. leathensis* and one of *Poraspis* sp., and 'in loose blocks on escarpment 500 yds. from church' some nearly complete dorsal and ventral disks of the *Pteraspis*.

8. *Near Brecon*

One, possibly two, specimens found south of Brecon recently by W. N. Croft, are interesting in that their horizons can be clearly related to the *Traquairaspis symondsi* horizon of Crwcas Wood (see White, 1946: 213, loc. 14, 'Crwcws Wood').

In Crwcas Lane, about 300 yds. east of Pen-y-lan farmhouse, 1 mile south of Brecon Castle, a small exposure has yielded a fair example of the ventral disk in counterpart of *P. leathensis* (P.26542–3). The level is about 710 ft. O.D., nearly 50 ft. above a 3-ft. limestone band and perhaps 100 ft. above the *Traquairaspis symondsi* horizon in Crwcas Wood, about $\frac{1}{4}$ mile to the north-west.

In the old quarry by Pen-y-lan farmhouse, some 300 yds. to the west of the above exposure, a single small fragment, possibly of this species (P.26541), has also been found. The top of the quarry is on the 770-ft. contour, so that the level is some 60 ft. above that of Crwcas Lane.

The record by Wickham King (1934: 541) of *P. leathensis* with '*Psammosteus anglicus*' from the flats on the south side of Caldy Island, Pembrokeshire (see White, 1946: 213), has not been confirmed.

III. PALAEONTOLOGY

As noted above, *Pteraspis leathensis* was recorded long before the species was described, at first as '*Cyathaspis leathensis*' and then under its present designation, and a fair number of specimens, collected by Wickham King from several localities and considered by him to be conspecific, were attributed to this undescribed form and were so labelled. The two most important localities from which such specimens came were 'Leath I' (or 'Leath Stream'; see p. 70 *supra*) and 'stream near Oldfield' which are about 7 miles apart. The first of these two localities was considered to be in Wickham King's stage I. 8, the second in I. 9, but the two series of fossils were generally similar in appearance comprising mostly fragments or isolated plates of a very small *Pteraspis*, black in colour in a grey matrix; and in the original description (White, 1935: 445, text-figs. 30, 31, 38, 77, 94) the two suites of fossils were accepted as being conspecific and the description and restoration based on them jointly. However, subsequent collecting from these, but more especially from other areas, has clearly shown that the fossils from the Oldfield section, which include the elongated

rostrum, belong to an unusually small form of another species, *P. crouchi*, and the restoration is therefore a chimaera, *P. leathensis* being in fact a round-snouted form similar to certain Continental and polar species, which are conveniently grouped together as a new sub-genus.

Genus *PTERASPIS* Kner 1847

(*a*) Sub-genus **Simopteraspis** nov.

(Gr. σιμός = snub-nosed)

DIAGNOSIS. Species of *Pteraspis*, generally of small size, with blunt rounded snout. Pineal plate small, more or less triangular and widely separated from orbital plates which are without medial extensions. Cornual plates small and triangular. Inter-orbital sensory canal forming long V-shaped loop on dorsal disk.

SPECIES. *P. leathensis* White, the sub-genotype; *P. gosseleti* Leriche; *P. primaeva* Kiaer; *P. vogti* Kiaer.

Pteraspis (Simopteraspis) leathensis White

(TEXT-FIGS. 2–14, 20; Pl. 5)

1921*b*. *Cyathaspis leathensis* W. W. King, p. 7 (*nomen nudum*).
1925. *Cyathaspis leathensis* W. W. King, p. 387 (*nomen nudum*).
1934. *Pteraspis leathensis* W. W. King, pp. 530, 534 (*nomen nudum*).
1935. *Pteraspis leathensis* E. I. White, p. 445, text-figs. 30, 38, 77, 94 (*non* 31).
1936. *Pteraspis leathensis* F. H. Edmunds & K. P. Oakley, p. 29 (name only).
1947. *Pteraspis leathensis* T. H. Whitehead & R. W. Pocock, pp. 11, 22, 23 (name only).

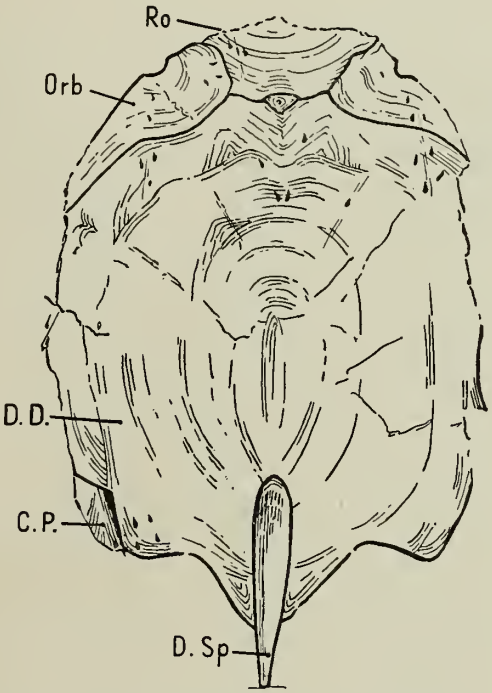
DIAGNOSIS. A *Simopteraspis* with dorsal shield attaining a length of 5 cm. without dorsal spine. Dorsal disk depressed in front but vaulted posteriorly with maximum breadth over curve nearly equal to length from tip of rostrum to end of spine socket; anterior margin of disk very short and usually deeply indented; antero-lateral margins gently concave; posterior margin concave on each side of pronounced median projection pierced by dorsal spine socket, which forms $\frac{2}{7}$ to $\frac{1}{3}$ length of disk and probably exceeds that of exserted portion of depressed, laterally compressed spine. Rostrum short, forming rather more than $\frac{1}{5}$ length of dorsal shield, and about $\frac{1}{8}$ longer than distance between orbital plates. Pineal plate very small, widely separated from orbital plates which have convex antero-medial margins but no medial extension, and slightly exceed in length distance between orbits. Cornual plates triangular, medium-sized, reaching forwards beyond level of spine-socket.

Ventral disk ovoid with short, flattened or emarginated anterior border and convex posterior margin with blunt median angle.

Ridges of external ornamentation numbering 50–80 per cm. and Λ-shaped in section. Variation in form and ornamentation of scales as in *P. rostrata toombsi* but transverse ridges rather more broken up and longitudinal ridges less subdivided posteriorly.

DESCRIPTION. The new material gives an entirely different picture of this important species from that given in the original description, and is almost complete in respect of the carapace. The best specimens are those from Ammons Hill (Text-figs. 3–5, 9), the first of which is the external impression of an almost entire dorsal shield.

This shield, comprising the rostrum, pineal plate, orbitals, dorsal disk, dorsal spine, branchial and cornual plates, is known in detail except for the extremity of the spine. The length of the adult dorsal shield as indicated by the largest specimens from Ammons Hill (Text-figs. 3, 4, &c.) reaches 5 cm. without the spine, and the Leath specimens (Text-fig. 2) are similar in size; but the Porch Brook shields are only three-quarters as large (Text-figs. 6–7) and seem to have relatively larger cornual plates, and



TEXT-FIG. 2. *Pteraspis* (*Simopteraspis*) *leathensis* White. External impression of flattened dorsal shield with imperfect rostral and branchial regions. The holotype, Leath Stream. [P.14521. ×2.]

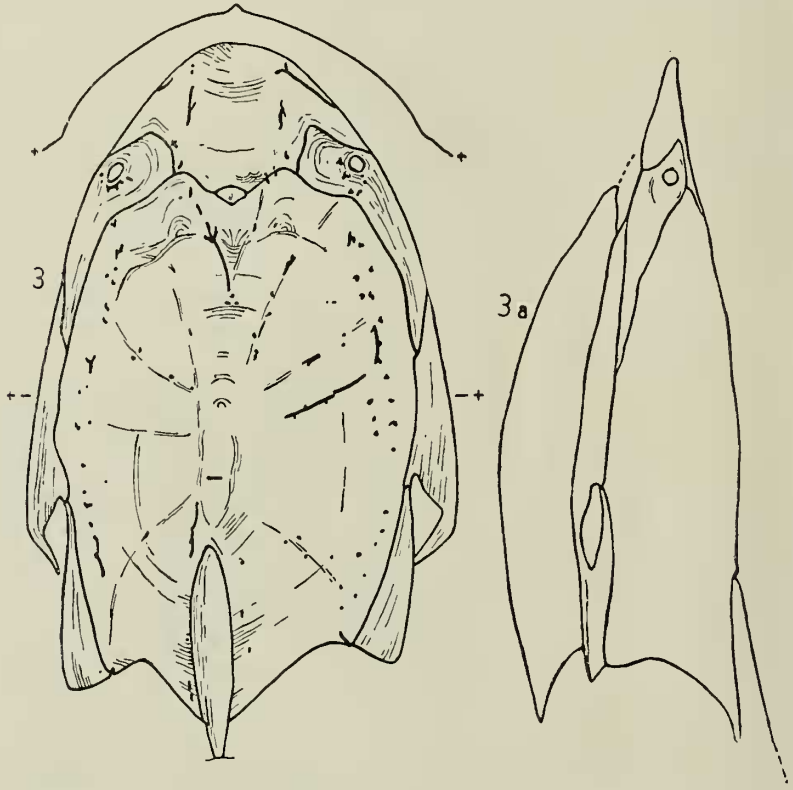
C.P., cornual plate; *D.D.*, dorsal disk; *D.Sp.*, dorsal spine; *Orb.*, orbital plate; *Ro.*, rostrum.

more distinct denticulation of the ridges of the ornamentation. These differences may be due to juvenility. The specimens from the Morville area provide intermediate types.

The rostrum is short and rounded, typical of this group of *Pteraspis*, while its posterior border is undulating to a degree seen in no other British species (Text-figs. 2–6; Pl. 5, Fig. 1). Its breadth between the orbitals is about $\frac{9}{10}$ that of the median length of the plate. The orbital plates, which are widely separated from the small pineal plate, have a sinuous margin with the dorsal disk, of which the antero-lateral corners are cut away, the anterior margin of this plate being very unlike that of other British species, all of which are a simple heart-shape in front. The hinder margin shows a strong median projection pierced by the large socket of the dorsal spine, but the spine itself is laterally compressed and short (Text-figs. 3, 4, 8; P.14522).

The branchial plates are long, and the cornual plates small and narrow in the Ammons Hill specimens (Text-figs. 3, 4), but rather wider and more triangular in those from Porch Brook (Text-fig. 7; Pl. 5, Fig. 2).

Text-fig. 7 shows a most remarkable specimen, the earliest instance of teratology in a vertebrate animal that I know. It is the left side of a blind monster of the small

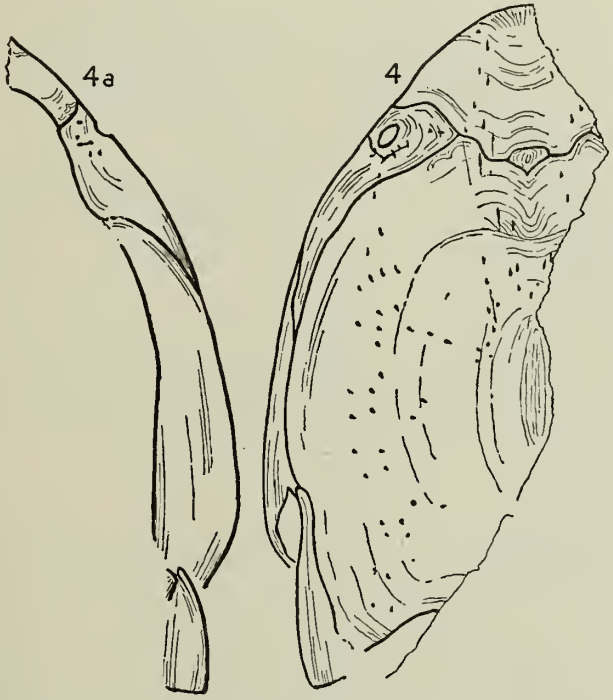


TEXT-FIG. 3. *Pteraspis* (*Simopteraspis*) *leathensis* White. External impression of complete dorsal shield, showing remains of sensory canals and pattern of ornamentation. +–+, cross-profile of internal cast. 3*a*. Side view with ventral disk added. Ammons Hill. [P.23014–5. × 2.]

Porch Brook series in which the branchial and cornual plates seem to be normal, but the hinder part of the orbital is fused with the dorsal disk, although its posterior point is indicated by a notch, and the discrete, anterior portion is triangular and without an orbit. The lower, outer part of the orbital sensory canal also seems to be missing. This abnormality would appear to be due to an injury received at a very early stage, before the plates were formed.

In regard to the ventral disk, little is to be added to the original description (White, 1935: 407, text-figs. 38, 77), but the specimen figured from Ammons Hill (Text-fig. 9) shows a well-developed 'pocket' for the insertion of the anterior ventral ridge-scale. No other plates of the carapace have been found.

Isolated scales (Text-figs. 10–14; Pl. 5, Figs. 3–5) are plentiful at both Porch Brook and Leath Stream, but only the former are well preserved. The same types of scales are found as in *P. rostrata* (White, 1935: 413, text-figs. 56–62, pl. 27) and the anomalous double scales are well represented. The ordinary flank-scales tend to be rather less regularly diamond-shaped and the anterior ridge-scales less pointed than in the

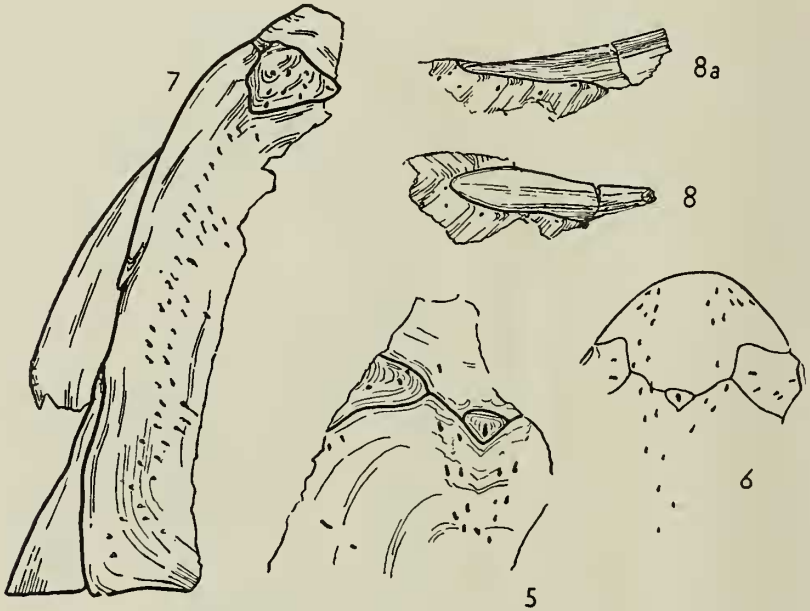


TEXT-FIG. 4. *Pteraspis* (*Simopteraspis*) *leathensis* White. External impression of right side of dorsal shield. 4*a*. Undersurface of rostrum, orbital, branchial and cornual plates respectively. Ammons Hill. [P.23018. × 2.]

bigger species. But the most interesting feature of these scales is their relatively enormous size and the large anterior areas of overlap. In size they are actually about the same size as those of *P. rostrata toombsi* although the shields are only $\frac{2}{5}$ as long, while one of the double flank-scales (RP311) is actually 6 mm. in height and is therefore as large as the giant scales of *P. rostrata* from Trimpley. Whether these scales do belong to the shields with which they are associated may be questioned, for it is possible that they were brought together by water-sorting—but no larger plates of this or any other contemporary species are known from the region.

The area of overlap is clearly shown in a number of specimens (Text-figs. 10–14). The surface is often crinkled and the free margin irregular, while the width varies greatly. This area of overlap is also seen in *P.* (*Rhinopteraspis*) *dunensis* (White, 1938, text-figs. 6–9), and it is obvious that such a feature was present in all species,

its absence in the numerous specimens of *P. rostrata* (White, 1935) is due to the chances of preservation—which is rather remarkable in view of the superb state of preservation of the specimens from Wayne Herbert and Trimpley. Recently a fresh examination has shown that this feature is partly preserved in one of the Trimpley scales (P.17444).



Pteraspis (*Simopteraspis*) *leathensis* White

TEXT-FIG. 5. External impression of pineal area of dorsal shield. Ammons Hill. [P.23793. × 2.]

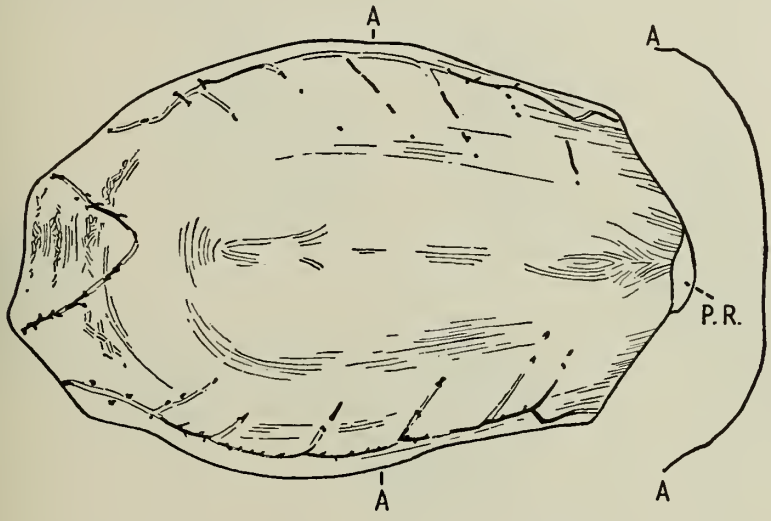
TEXT-FIG. 6. Rostral area of small dorsal shield (see also Pl. 5, Fig. 1). Porch Brook. [B.U.487. × 2.]

TEXT-FIG. 7. Left side of dorsal shield of abnormal, blind specimen without orbit and with hinder part of orbital plate fused with dorsal disk. Porch Brook. [B.U.488. × 3 approx.]

TEXT-FIG. 8. Imperfect dorsal spine and socket, in dorsal and (*a*) lateral views. Porch Brook. [B.U.489. × 2.]

The ornamentation follows the usual pattern of the genus (Pl. 5, Figs. 1, 2) and comes within the usual range of fineness (50–80 ridges per cm.; see White, 1938: 107). The individual ridges are ∧-shaped in section with fine but conspicuous denticulation when unworn. A feature of this species is the marked irregularity of the ridges at the beginning of the later growth-stages, especially on the dorsal and ventral disks, as indicated by the extreme unconformity between the ridges outside the major-growth lines. In the holotype (Text-fig. 2) two such stages are shown, in the large disks from Ammons Hill only one (Text-figs. 3, 4, 9), but in the little specimen from Porch Brook (Pl. 5, Fig. 1) there is none, which suggests that it is not fully grown. These

irregularities seem to indicate the resumption of rapid growth after a resting period. The ornamentation in the antero-lateral marginal area of the ventral disk is often broken up into confused short lengths or tubercles (Text-fig. 9), and in the centre of this plate confused areas are also sometimes to be seen (P.16853*i*).



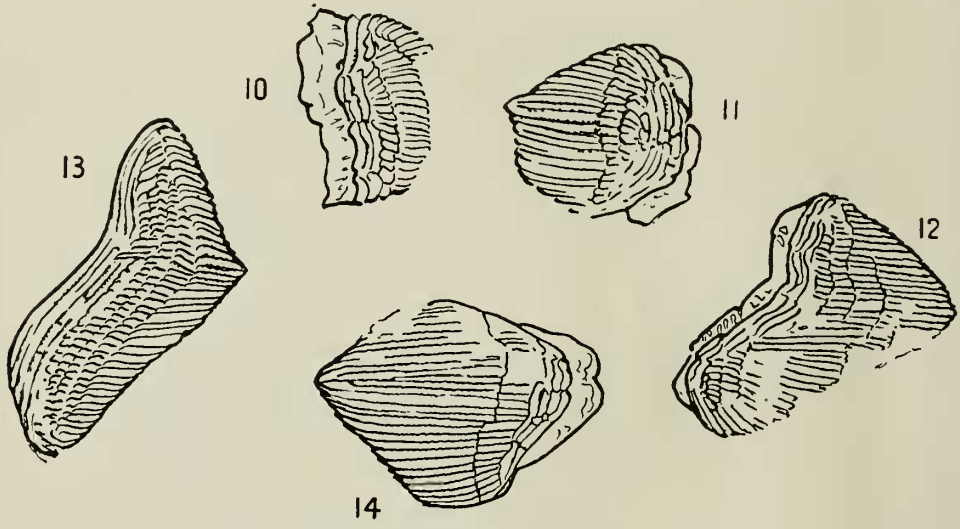
TEXT-FIG. 9. *Pteraspis* (*Simopteraspis*) *leathensis* White. External impression of ventral disk showing sensory canals, with cross-profile of internal cast at A.A. Ammons Hill. [P.23016–17. × 2¼ approx.] *P.R.*, 'pocket' for insertion of anterior ventral ridge-scale.

The ornamentation of the scales resembles that of *P. rostrata toombsi* (White, 1935: 419, pl. 27, figs. 107–9) in that it consists of a series of longitudinal ridges divided in front into short lengths by transverse grooves which are usually preceded by a number of transverse ridges parallel with the anterior margin of the scale (Text-figs. 10–14; Pl. 5, Figs. 3–5)—but both transverse ridges and grooves are fewer than in the *P. rostrata toombsi* (in *P. rostrata trimpleyensis*, on the other hand, the transverse ridges are absent; see White, 1935, text-figs. 56–62).

Of the sensory canal system it may be noted that the 'inter-orbital' canal, instead of running through the pineal plate immediately behind the pineal macula as in other British species in which it is known (see White, 1935, text-figs. 26, 66, 68–9, 81), runs back to form a long V-shaped loop in the dorsal disk, as in the Spitsbergen species *P.* (*S.*) *primaeva* (Kiaer, 1928, text-fig. 1), and in the French *P.* (*S.*) *gosseleti* (Text-fig. 15). It is probably a feature common to all species of the sub-genus. The inner longitudinal canals vary considerably in their position relative to the inter-orbital loop and may be widely separated from it (Text-figs. 2, 3) or run close by it (Text-fig. 4).

COMPARISON WITH OTHER SPECIES. The first of the short-snouted species of *Pteraspis* to be described was *P. gosseleti* Leriche (1906: 26, text-fig. 8, pl. i, figs. 6–9)

from the 'Passage Beds' (Psammites de Liévin) of the Pas-de-Calais (see Barrois, Pruvost, & Dubois, 1922: 180–4). Thanks to the kindness of Professor Leriche and Professor Pruvost I have been able to examine these specimens from the collections of the University of Lille. There are four dorsal shields, two of which are nearly complete (Text-figs. 15–17, 19), but the surface of the plates has almost disappeared and



Pteraspis (*Simopteraspis*) *leathensis* White

Text-fig. 10. Imperfect left flank-scale with exceptionally large area of overlap. [B.U.492.]

Text-fig. 11. Right flank-scale, probably from near top of series. [B.U.493.]

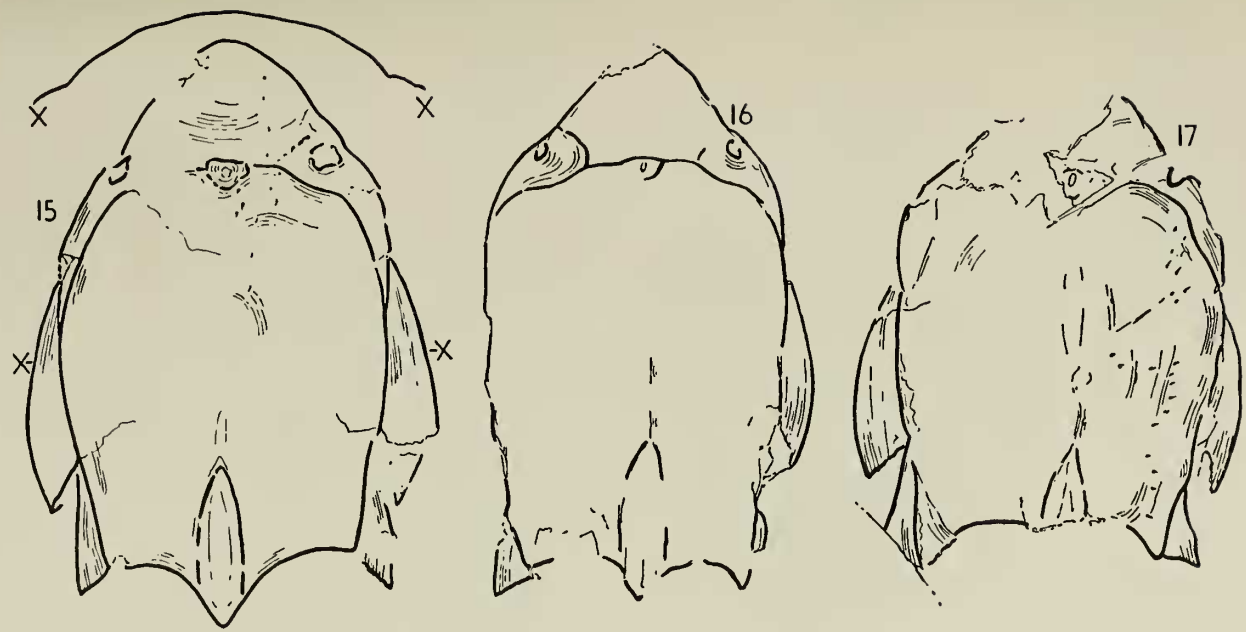
Text-figs. 12, 13. Double flank-scale, probably from right flank and therefore covering two diagonal rows, but orientation not certain. If inverted each would cover the area of two scales in the same row. In Fig. 13 the area of overlap has been broken away. [B.U.490, RP700.]

Text-fig. 14. Anterior ridge-scale. [RP718.]

All specimens from Porch Brook. × 8.

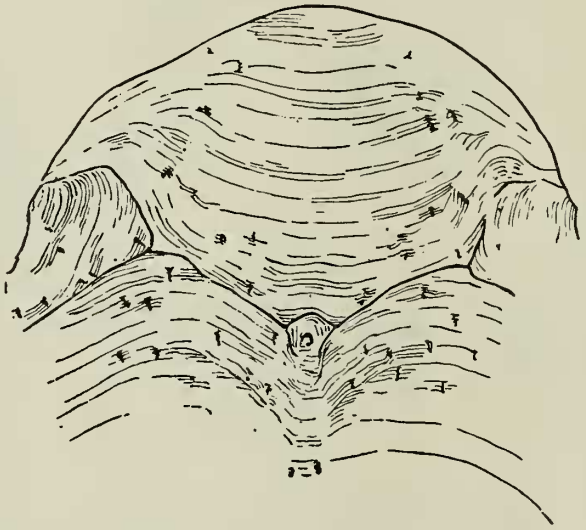
very little is left of the ornamentation, so that the outlines of the individual plates are most difficult to determine, especially in the pineal and orbital region. The largest is rather smaller than the Ammons Hill specimens, having a median length of 40 cm., while the smallest is about the size of the Porch Brook series. There seems little or no difference between the French and English specimens in proportions when allowance is made for curvature, but so far as one may judge, the former have a relatively larger pineal plate, a larger base of the dorsal spine, and shorter cornual plates, while the rostrum seems more acute (cf. Text-figs. 19–20). It is, however, not impossible that when well-preserved specimens of *P. gosseleti* are forthcoming the two forms may prove to be conspecific.

Pteraspis vogti has not yet been described and our published knowledge of it is confined to the famous restoration of the undersurface of the carapace showing the mouth-parts and on photographs of this region (Kiaer, 1928: 119, text-fig. 2, pl. xii). Professor Anatol Heintz has, however, kindly compared photographs and drawings



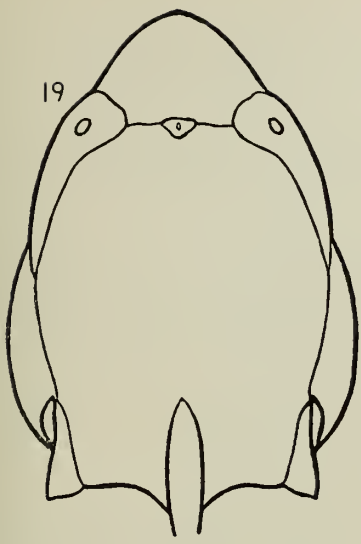
TEXT-FIGS. 15–17. *Pteraspis* (*Simopteraspis*) *gosseleti* Leriche. Three of the four syntypes. The original of Fig. 15 is hereby chosen as the lectotype. *x–x*, Cross-profile. Psammites de Liévin, Pas-de-Calais. [Univ. Lille. × 2.]

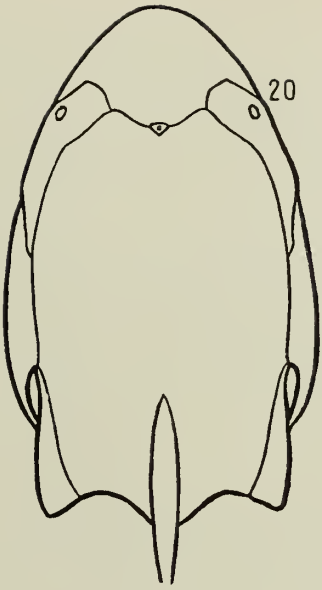
of *P. leathensis* with specimens of the Spitsbergen species and sent me photographs on which Text-figs. 18 and 21 are based. *P. vogti* attains a substantially greater size than the English species and appears to be somewhat broader and flatter with a shorter and more rounded rostrum, smaller orbital plates, and finer ornamentation. According to Føyn & Heintz (1943: 43) *P. vogti* is known only from the basal layers of the Ben Nevis Division, which they equate with the Dittonian.

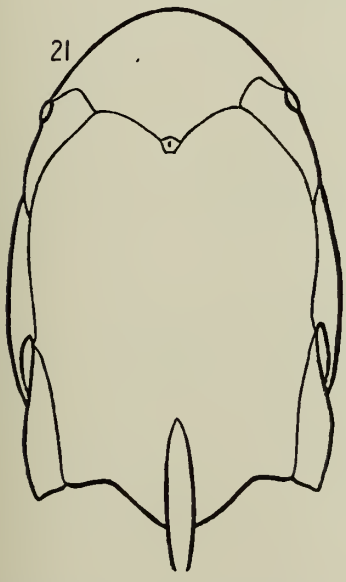


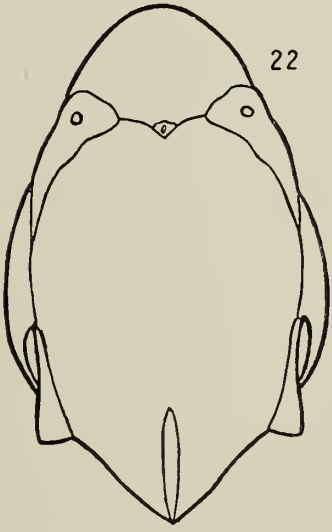
TEXT-FIG. 18. *Pteraspis* (*Simopteraspis*) *vogti* Kiaer. Rostral and pineal region, showing external pores of sensory canal system and distribution of ornamentation. Base of Ben Nevis Division, Spitsbergen. [From a photograph by A. Heintz. × 3 approx.]

The second species from Spitsbergen, *P. primaeva*, is also as yet undescribed, but Kiaer (1928, text-fig. 1) has published a restoration of the dorsal shield. Professor Heintz informs me that this species is similar in size to *P. leathensis*, but that the ornamentation is finer. The restoration (Text-fig. 22), which again is based on photographs sent by Professor Heintz and differs in some details from Kiaer's, suggests that the cornual plates are smaller, that the orbitals are smaller and of different shape, and that the posterior angle is much more pronounced and entirely occludes the socket of the dorsal spine, which seems to have been more elevated than in the other species; but what Professor Heintz considers to be most significant is that the inside of the shield clearly shows the impression of the semicircular canals and gill-sacs, as in *Poraspis* and *Anglaspis*, indicating that growth of the plates was much more limited than is normal in *Pteraspis*. *P. primaeva*, Professor Heintz informs me (*in lit.* 11 Sept. 1946), is from the *Poraspis* horizon in the middle of the Fraenkelryggen Division of the Red Bay Series. At the base of the Fraenkelryggen Division both *Corvaspis* and *Traquairaspis* [*Phialaspis*] occur (Føyn & Heintz, 1943: 43), which at once recalls the fauna of Earnstrey Brook in the zone of *T. symondsi* (White, 1946:









TEXT-FIGS. 19–22. Restorations of dorsal shields of species of *Pteraspis* (*Simopteraspis*). Fig. 19. *P.* (*S*). *gosseleti* Leriche; × 2. Fig. 20. *P.* (*S*). *leathensis* White; × 1½. Fig. 21. *P.* (*S*). *vogti* Kiaer; × 1⅓. Fig. 22. *P.* (*S*). *primaeva* Kiaer; × 2.

210), so that the middle beds with *Pteraspis primaeva* may be readily correlated with the zone of *P. leathensis* which is here taken as the base of the Dittonian, and thus according to our classification only the lowest part of the Fraenkelryggen Deposits are of Downtonian age.

It is interesting to note that the small ventral disks from the Knoydart Formation of Nova Scotia, to which the name *P. novae-scotiae* has been given (White, 1935: 444), resemble those of *P. leathensis* in size and in the Λ-shape of the ridges of the ornamentation.

To sum up we may say that the appearance of the blunt-snouted forms (*Simopteraspis*) in the distant Spitsbergen area was at about the same time as in England, while on the other side of the Channel we may with some assurance correlate our '*P. leathensis*' beds (here regarded as the base of the Dittonian) with the beds containing *P. gosseleti* (Psammites de Liévin).

(*b*) **Pteraspis crouchi** Lankester

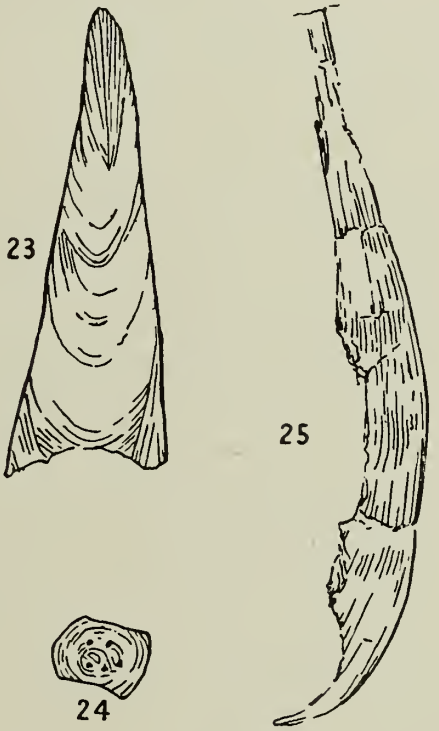
(Text-figs. 23–5)

The original specimens from Oldfield which were ascribed to *P. leathensis* consisted of one rostrum in counterpart, two fragments of rostra, and a lateral plate (P.16851, 2, 4–6). The material which has newly come to hand and which fixes beyond doubt the identity of the species comprises a rostrum (RP461), two imperfect dorsal disks (B.U.333/38, 503), parts of two ventral disks (B.U.500–1), an orbital (B.U.504) and an imperfect branchial plate (B.U.502). Most of the specimens call for little comment except in regard to their uniformly small size, and all are coloured black on a dark grey matrix, very like the specimens of *P. leathensis* from Leath Stream with which they were originally associated. The new rostrum (Text-fig. 23) is defective at the base, but shows the tip which was missing in the original specimen referred to *P. leathensis* and is very slender, measuring over 2 cm. in length and not more than 0·6 cm. across the base as preserved. The other plates are correspondingly small, except the unique polygonal anterior lateral (Text-fig. 24), very like that of *P. rostrata*, which measures 4·5 cm. by 3·5 cm. and seems to belong to an animal three-quarters fully grown, and an anterior piece of the ventral disk representing a fully grown plate some 6 or 7 cm. in length. The branchial plate (Text-fig. 25), like the anterior lateral, is the only known example referable with some certainty to this species. That this plate should be so rare is remarkable, since numerous dorsal shields of this species have been collected within recent years showing the rostrum, pineal plate, orbitals, dorsal disk, and spine all firmly fixed together but never with any evidence of a branchial or cornual plate, whereas in the contemporary *P. rostrata* these are commonly found attached (see White, 1935). The specimen does not differ markedly from the corresponding plate in *P. rostrata*, unless the anterior end, which is imperfect, tapers more. As preserved it is 3·2 cm. long.

No cornual plate has been found in this or among the other plentiful British material, while the single specimen recorded from the Continent (Leriche, 1924, pl. iii, figs. 8, 9) seems too conspicuous a plate not to have been found elsewhere and may not belong to this species. Indeed, one may reasonably expect the cornual plates of

P. crouchi to be even more diminutive than those of *P. rostrata* and the slenderness and length of the branchial plate seems to support this suggestion.

LOCALITY. The specimens came from sections in a stream near 'the Lobby', Oldfield, near Chetton, 4 miles south-west of Bridgnorth. The beds are in a small area determined as stage I. 9 by Wickham King, who separates it by faults from the



Pteraspis crouchi Lankester
TEXT-FIG. 23. Rostrum lacking proximal end. [RP461.]
TEXT-FIG. 24. Anterior lateral plate. [P.16856.]
TEXT-FIG. 25. Imperfect branchial plate. [B.U.502.]
All specimens from Oldfield. × 3.

surrounding rocks, similar in level but referred to stages II. 2–3. However, it seems likely that the stage was determined on the basis of the specimens being misidentified as *P. leathensis*, and there is no reason to suppose that the zone is in fact different from that of the surrounding strata, so that the need for the faults disappears. The section is described by Whitehead & Pocock (1947: 23).

REMARKS. From no other recorded locality in this country are the specimens of *P. crouchi* so uniformly small; indeed specimens so small as this are altogether extremely rare, and in the British Museum Collection there is only a single dorsal disk from Pool Quarry (P.24468–9) apart from a remarkable series from Cwm Mill, near Abergavenny, discovered by W. N. Croft, in which dorsal disks ranging from less

than 2 cm. long (P.25071) to those of fully grown adults three times the size (P.25115) are present. It is interesting to note that in the only two satisfactorily illustrated records of this species outside England and Wales, from the Upper Gedinnian of the Pas-de-Calais (Leriche, 1903, pls. v–vi; 1906: 27, pl. ii) and Belgium (Assise-de-Fooz, Leriche, 1924, pl. iii), most of the specimens are of the same diminutive size as those from Oldfield. The evidence of the Cwm Mill series suggests that these stunted forms are not due to the segregation of half-grown animals, in spite of the absence of growth stages, but to partly uncongenial conditions.

We may appropriately comment here on the range of *Pteraspis crouchi* in general and of its congener, *P. rostrata*.

These two species, as noted above, have never been found in association with *P. leathensis* and the vast majority of their occurrences are in beds clearly above the known range of that species. The range of *P. leathensis*, as previously shown, may possibly include at times elements of the '*Psammosteus* Limestones' phase at its base, but is usually a little higher and continues upwards to constitute a relatively thin zone, possibly up to 70 ft. in thickness; that is to say, in Wickham King's classification, the upper part of stage I. 8 and most of stage I. 9 (see Text-fig. 1). *P. crouchi* and *P. rostrata* are said to be exclusively Dittonian in the original sense (King, 1925: 386), and therefore some 190–300 ft. above the '*Psammosteus* Limestones' (King, 1934: 527). However, at Targrove $2\frac{1}{4}$ miles north-north-east of Ludlow, *P. rostrata trimpleyensis* (B.M.(N.H.) 35998, 45963–4) has been found in strata about 100 ft. above the '*Psammosteus* Limestones' and 20 ft. below the '*Cephalaspis* Sandstone' shown on King's MS. 6 in. map; while at the Old Furnace Quarry, Bouldon, $6\frac{3}{4}$ miles north of Ludlow, specimens of *P. rostrata* (Geol. Surv. No. 53303) and Cephalaspids have been found in strata which Wickham King (1925: 385) considered to be in stage I. 9, 100 ft. above the nearest representative of the '*Psammosteus* Limestones'. Moreover, a specimen of *P. crouchi* (P.23772) was obtained between 50 and 100 ft. above the limestones at Pen-y-bwr Quarry, Dorstone, Herefordshire, by H. A. Toombs.

In none of these localities has *P. leathensis* been found, so that the relationships between its zone and that of *P. crouchi* cannot be directly determined, but their relative positions are clear and there is no evidence that they overlap.

The upper limit of the zone of *P. crouchi* is not clear, for the Dittonian becomes marly and more rarely fossiliferous the higher one goes, although some well-known '*crouchi*' localities, like Acton Beauchamp, are fairly high up in the sequence.

Finally, as on many previous occasions, I have to acknowledge the generous assistance given to me by Mr. Wickham King, Professor L. J. Wills (who provided the photographs for the plate), Dr. R. W. Pocock, and Mr. H. A. Toombs; in addition my thanks are especially due to Professor Anatol Heintz, of Oslo, who not only gave me much valuable information concerning the Spitsbergen species, but also sent a fine series of photographs for purposes of comparison; to Professor Maurice Leriche and Professor Pierre Pruvost, through whose kindness I was able to examine the original specimens of *Pteraspis gosseleti* from the collections of Lille University; and to Dr. C. J. Stubblefield, F.R.S., through whose ready co-operation the collections of H.M. Geological Survey have always been accessible to me.

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